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SCANNER AND METHOD FOR SWEEPING A BEAM ACROSS A TARGET

Field of the Invention

[1] The present invention relates to optical imaging systems and, more particularly, to an imager that employs one or more scanned beams of light to image all or a portion of a target object.

BACKGROUND OF THE INVENTION

[2] A typical bar code system may employ components that include a light source, a scanner, an optical detector and a processor. The light source projects a light beam at an oscillating scanner that sweeps the light beam in a scan pattern onto a bar-code symbol. The optical detector receives light reflected from the bar-code symbol and generates a signal that the processor converts into a data stream. The data is analyzed to determine a particular meaning for the scanned bar-code symbol.

[3] A typical width-modulated linear bar code symbol includes parallel bars and spaces of varying widths extending in a common direction (Y). By scanning a beam of light across the bars and spaces along an axis roughly perpendicular to their long axes (X), and analyzing the light reflected, the scanned bar code symbol can be associated with a particular symbology. A particular bar code symbology comprises a set of encoding and decoding rules, rules for recognizing the symbology, and, , rules for error detection and correction. The encoding rules associated with the particular symbology may include provision for encoding letters, symbols and other types of information.

[4] Symbols are not necessarily limited to one-dimensional patterns. Recently, two-dimensional (2D) symbologies have gained favor due to their generally higher data capacity, higher encodation efficiency, and forward error correction. Two current types of 2D symbols are 2D stacked symbols and 2D matrix symbols.

[5] 2D stacked symbols generally comprise a plurality of width modulated segments, the segments usually being stacked vertically such that their individual bars

and spaces extend along a Y axis with data encoded in their widths along an X axis. In addition to encoding data, each segment often includes means for encoding its position in the stack of segments, for instance by its parity pattern or by location characters appended to the beginning and/or end of the segment. Thus, according to the decoding rules associated with a 2D stacked symbology, a 2D stacked symbol constructed according to those rules may be decoded after scanning each of its segments, with such scanning being performed in no particular order. The inclusion of location data with each segment allows a wide variety of data collection devices to be used to read 2D stacked symbols, including those capable of making measurements along only a single axis.

[6] 2D matrix symbols encode their data by the presence or absence of marks across a two-dimensional array of locations or cells, such presence or absence determining the value of a particular cell. The encoding and decoding rules for a 2D matrix symbology include at least one defined method for determining the presence of a symbol within a two-dimensional field-of-view (FOV), determining the extent of the symbol within that FOV, and determining the position of each cell within that extent. Additional rules then define at least one procedure for assembling the detected cell values into data words, and the data words into one or more messages encoded within a symbol. Because data is encoded in locations along both axes of a symbol, 2D matrix symbols are readable only by devices that can detect, or at least infer, two axes within an FOV. In contrast to a 2D stacked symbol, the data in a particular row of most matrix symbols does not, in itself, contain information as to its whereabouts within the symbol.

[7] Many readers compatible with 2D symbols and particularly 2D matrix symbols include two-dimensional detector arrays, for instance CCD or CMOS arrays, that produce a digital representation of a region of a target object. The reader then employs signal processing, such as finder algorithms and decode rules to locate and decode any symbols on the object.

[8] Structurally, common commercial hand held scanner systems typically include a hand held unit that includes a light emitter, scanner, and detector in a single

unit. A remote base unit carries a battery that powers the handheld portion. Usually, the operator wears the remote base unit in a hip pack or another similar arrangement. The base unit often includes a processor that analyzes and decodes symbols and controls the handheld portion through a wiring harness.

[9] Variety of approaches have been demonstrated for handheld bar code scanning. Some of these approaches are presented in U.S. patents numbers 5,671,374, 5,665,956, 5,583,331, 5,521,367, 5,519, each of which is incorporated herein by reference.

SUMMARY OF THE INVENTION

[10] In an embodiment of the invention, a scanner includes a scan-beam generator, a beam reflector having a first magnet, and a beam-sweep mechanism having a second magnet. The beam-sweep mechanism causes the reflector to sweep the scan beam by exerting a force on the first magnet with the second magnet.

[11] Such a scanner can scan targets such as bar codes, and typically uses less electrical power and is smaller than bar-code scanners that have a motor to spin the beam-sweep reflector.

BRIEF DESCRIPTION OF THE DRAWINGS

[12] **FIGS. 1-20** are described in the Description Of The Invention below.

[13] **FIG. 21** is an exploded view of a handheld scanner that sweeps a scan beam using kinetic energy supplied by an operator according to an embodiment of the invention.

[14] **FIG. 22** is an isometric view of the beam source of **FIG. 21** where the beam-reflector assembly is in its home position according to an embodiment of the invention.

[15] **FIG. 23** is an isometric view of the beam source of **FIG. 21** where the beam-reflector assembly is in its zero sweep position according to an embodiment of the invention.

[16] **FIG. 24** is an isometric view of the beam source of **FIG. 23** showing the scan beam and the reflected return beam according to an embodiment of the invention.

[17] **FIG. 25A** shows the beam-reflector assembly and the home and sweep positions of the beam-sweep-mechanism magnet according to an embodiment of the invention.

[18] **FIG. 25B** is an isometric view of the beam-sweep-mechanism magnet of **FIG. 25A** according to an embodiment of the invention.

[19] **FIG. 26** is side view of the beam-reflector assembly and the beam-sweep mechanism of **FIGS. 22 - 24** according to an embodiment of the invention.

[20] **FIG. 27** is an isometric view of the magnet, magnet holder, and magnet retainer of the beam-sweep mechanism of **FIGS. 22 – 24** according to an embodiment of the invention.

[21] **FIG. 28** is an isometric view of the beam source of **FIGS. 21 - 24** having a trigger mechanism in an up position according to an embodiment of the invention.

[22] **FIG. 29** is an isometric view of the beam source of **FIG. 28** where the trigger mechanism is in a down position according to an embodiment of the invention.

DESCRIPTION OF THE INVENTION

[23] **FIG. 1** illustrates one embodiment of a bar code scanning system ***100*** that includes an optical emitter ***104***, a scanner ***102*** that is user powered, a detector ***108*** and a processor ***112*** within a controller ***135***. The emitter ***104*** includes light source that is enabled by the trigger and powered by a battery. The emitter ***104*** emits a light beam ***130*** toward the scanner ***106*** and the scanner redirects the light beam ***130*** toward a symbol ***190*** on a target object ***192***. As is typical, the symbol ***190*** includes a number of regions of differing reflectivity, as described previously.

[24] The optical emitter may generate optical energy at a particular wavelength that may or may not be visible with a light emitting diode (LED) or laser diode. Also, the emitter may include a full spectrum light source such as a mercury vapor lamp, short arc lamp or a white laser diode. Other types of emitters include electro-luminescent,

incandescent, vacuum emissive, fluorescent, chemical emissive, phosphorescent, and field-emissive.

[25] The symbol ***190*** reflects a portion of the light from the light beam ***130***, depending upon the respective reflectivities of the regions struck by the beam ***130***. As represented by the arrow ***135***, a portion of the reflected light is gathered by a gathering lens ***111*** and strikes the detector ***108***. The amount of reflected light incident upon the detector ***108*** is dependent upon several factors including wavelength, scanner position, detector position, any associated gathering optics, and the reflectivity of the symbol ***190***. The detector ***115*** may be a conventional electronic device, such as a photodiode or a CCD. Responsive to the light ***135***, the detector ***108*** produces an electrical signal.

[26] The processor ***112*** receives the signal and converts the received signal into a digital representation of an image of the symbol ***190***, i.e., the areas of the symbol that reflect the scanned light beam ***135*** onto the detector ***108***. The processor ***112*** or another component such as a digital signal/image processor identifies information represented by the symbol ***190***, responsive to the digital representation. For example, the processor ***112*** may identify the target object ***192*** or may determine characteristics such as a shipping date, destination, or other information. Alternatively, the identified information may be not pertain directly to the target object ***192***. For example, where the target object ***180*** is an identification card, the symbol may provide information about the holder.

[27] **FIG. 2** shows diagrammatically one embodiment of a user powered scanner ***102*** that includes a mirror ***107*** carried by an oscillating body ***108***. The scanner ***102*** does not require a separate electrical power source for operation, but instead is initiated into oscillations by mechanical energy that a user applies by depressing a trigger ***110***. In other embodiments, the scanner ***102*** may be powered by electrical energy derived from the user's input mechanical energy. Though **FIG. 2** shows the coupling between the trigger ***110*** and the oscillating body ***108*** as a simple member ***120*** for clarity, a variety of structures and approaches for transferring energy may be within the scope of the invention.

[28] **FIG. 3** shows one approach to driving a scanner ***302*** with user supplied energy. In this approach, the member ***120*** drives a slider bar ***122*** guided by track ***124***. The upper edge of the slider bar ***122*** includes a series of rounded teeth ***126A*** that move longitudinally as the member ***120*** drives the slider bar ***122*** along the track ***124***, as indicated by the arrow ***128*** and the broken lines ***126B***, ***126C***. The slider bar ***122*** and teeth ***126A*** are injection molded from a durable, substantially rigid plastic.

[29] A flexible member ***135*** of injection molded flexible plastic is positioned above the slider bar ***122*** and carries a mirror ***132***. A finger ***134*** projects downwardly from the flexible member ***135*** to engage the teeth ***126A***. The finger ***134*** is a plastic selected for relatively low sliding friction as the finger ***134*** engages the teeth ***126A***.

[30] As the teeth ***126*** a slide longitudinally, they drive the finger ***134*** through a periodic up-and-down path. The moving finger ***134*** bends the member ***120*** correspondingly and thereby drives the mirror ***132*** through a series of positions and orientations defined by the teeth ***126A*** and the member ***135***, as indicated by the broken line drawings of the member ***135*** and mirror ***132***. As described above, as the mirror ***132*** moves through its series of positions and orientations, and scans the beam ***130*** through a scan path.

[31] A similar approach is shown in **FIG. 4** in which the member ***135***, mirror ***132***, and finger ***134*** are structured similarly to those of **FIG. 3**. However, in this embodiment, the member ***120*** is replaced by placing teeth ***140*** directly on a trigger ***142***. As the user to presses the trigger ***142*** by applying a force ***144*** the trigger ***142*** pivots about an axle ***146***, thereby carrying the teeth ***140*** is passed the finger ***134***, as indicated by the arrow ***148***. As with the embodiment described above with reference to **FIG. 3**, the moving teeth ***140*** push the finger ***134*** to drive the mirror ***132*** through a series of positions and orientations. As the mirror ***132*** moves, it scans the beam ***130*** periodically.

[32] And still another approach, shown in **FIG. 5**, the user applies a force to 50 on a lever arm ***252*** to cause a lever assembly ***254*** to pivot about an axle ***256***. As the user begins to compress the lever arm ***252***, a torsion spring ***258*** provides a resistive force in biases the lever assembly ***254*** outwardly as indicated by the arrow ***259***.

Initially, the lever assembly ***254*** pivots about the axle ***256*** causing a distal portion ***260*** to push on a tab ***262*** at a distal end of the flexible member ***120***. As the distal portion ***260*** pushes on the tab ***262***, the flexible member ***120*** bends downwardly providing additional resistance to the lever arm ***252***. As the user increases force on the lever arm ***252***, the flexible member ***120*** bends sufficiently to strike a stop ***264***. As the flexible member ***120*** strikes the stock ***264***, it actuates a switch that turns on a laser assembly ***266***. The laser assembly ***266*** is oriented such that light emitted by the laser assembly reflects off of the mirror ***132*** and travels to a box generator ***268***. The box generator is an optical element that converts the beam ***130*** to a recognizable finder pattern that allows the user to more easily align the reader to the target object (not shown).

[33] When the user increases force again, the lever assembly ***254***, guided by a slot ***270*** slides longitudinally along the axis indicated by the arrow ***272***. As the lever assembly ***254*** slide longitudinally, the distal portion ***260*** releases force on the tab ***262***, thereby releasing the flexible member ***120***. Upon release, the flexible member springs toward its original rest position pivoting the mirror ***132*** through a series of positions and orientations. The moving mirror ***132*** sweeps the beam ***130*** through a scan path that exits through a window ***274*** toward the target object (not shown). In one approach, the laser assembly remains activated until the flexible member ***120*** moves the mirror ***132*** to its rest position. Alternatively, a simple timing circuit maintains power to the laser assembly for a selected time period sufficient to allow the mirror ***132*** to scan the beam ***130*** through the scan path.

[34] While the previously described embodiments utilize a mirror ***132*** carried directly by the flexible member ***120***, an alternative approach utilizes a resonant scanning assembly ***280*** carried by the flexible member ***120*** as presented in **FIG. 6**. In this embodiment, the user applies a force ***282*** to a button ***284*** pivotably or flexibly coupled to a housing ***286*** by an arm ***288***. As the user depresses the button ***282***, a distal tip ***290*** flexes the flexible member ***120***. Once the flexible arm on 20 is depressed sufficiently such that the distal tip ***290*** no longer engages the flexible arm ***120***, the flexible arm becomes free to spring back to its original position. When the flexible arm on 20 reaches the original position and strikes a stop ***292*** where it stops abruptly.

[35] Because the motion of the resonant scanning assembly ***280*** is interrupted abruptly, a portion of its kinetic energy causes resonant motion of the scanning assembly ***280***. To improve the energy transfer, the resonant scanning assembly ***280*** includes a mass ***601*** that is off center from its center of rotation. Once the resonant scanning assembly ***280*** begins rotating about its center of rotation, the resonant scanning assembly ***280*** "rings" for a period of time and with the amplitude defined by its parameters, including its Q. As will be described below, the resonant scanning assembly ***280*** includes a mirror that sweeps through a series of positions as part of the resonant movement. In a similar fashion to the above described embodiments, the reader can use the resonant motion of the mirror to sweep the beam ***130*** through a scan path.

[36] Another approach to actuating the resonant scanning assembly ***280***, shown in **FIG. 7**, includes a ratchet wheel ***602*** with several fingers ***604*** spaced along its periphery. The user actuates the ratchet wheel by depressing a button ***606*** that drives a rack ***608*** having several gear teeth ***610*** along one edge. The user's force pushes the rack longitudinally such that the teeth ***610*** engage complementary teeth ***612*** on an axle ***614***. The traveling rack ***608*** and thus imparts rotational motion to the axle ***614***. The turning axle ***614*** rotates the ratchet wheel ***602***.

[37] As the ratchet wheel turns, it bends a flexible arm ***616*** that carries the scanning assembly ***280***, until a distal end ***618*** of the flexible arm ***616*** reaches one of the fingers ***604***. As the distal end ***618*** passes the fingers ***604***, the flexible arm ***616*** straightens driving the distal end ***618*** against the ratchet wheel ***602***. The distal end ***618*** strikes the ratchet wheel ***602***, thereby abruptly stopping travel of the distal end ***618***. Because the flexible arm ***616*** carries the scanning assembly ***280***, the scanning assembly ***280*** moves as the flexible arm ***616*** bands and returns to its original position as the flexible arm ***616*** straightens. The impact of the distal end ***618*** on the ratchet wheel ***602*** stops the scanning assembly ***280***. However inertia causes the weight ***601*** to continue along the return path causing a central portion ***622*** to pivot. The central portion ***622*** oscillates about its axis of rotation and amplitude and frequency defined by the parameters of the scanning assembly ***280***.

[38] Another embodiment of a user powered scanner, shown in **FIG. 8**, the user depresses a button ***702*** to move an actuator arm ***704*** days pivotably coupled to the actuator ***702*** and a first end ***706***. In opposite and ***708*** of the actuator ***704*** moves through a guide groove ***710*** as the user depresses the button ***702***. As the user begins depressing the actuator ***702***, a tab ***712*** near the second end ***708*** of the actuator arm ***704*** depresses a finger ***714*** days coupled to a flexible beam ***716***. Because a base end ***719*** of the beam ***716*** is held securely to a housing ***724***, the depressed finger ***714*** causes the flexible beam ***716*** to bend. As the flexible beam ***716*** bends, it carries a mirror ***718*** from a rest position to a flexed position.

[39] As the user presses the button ***702*** farther, the guide groove ***710*** guides the tab ***712*** away from the base end ***719*** until the tab ***712*** disengages the finger ***714***, releasing the flexible beam ***716***. Upon being release, the flexible beam ***716*** travels back through its rest position and bends in opposite direction, carrying the mirror ***718*** with it. The beam ***716*** continues to flex back and forth sweeping the mirror ***718*** repeatedly through a diminishing scan path.

[40] In another embodiment, shown in **FIGS. 9A-9D**, a flexible arm ***802*** once again carries a mirror ***804***. The user actuates scanner by depressing a button ***806*** to pivot a drive arm ***808*** about an axle ***810***. As the drive arm ***808*** pivots, a tab ***812*** bends the flexible arm ***802*** by pushing the finger ***814***, thereby moving a mirror ***801*** about the axle ***810***, as shown in **FIG. 9B**. As the user depresses the arm even farther, the flexible arm ***808*** reaches a stop ***820*** that precludes further movement of the distal end of the flexible arm about the axle ***810***, as is visible in **FIG. 9C**. In response to further depression by the user, the distal end of the flexible arm ***808*** moves longitudinally along the stop ***820*** as indicated by the arrow ***822*** in **FIG. 9D**. As the distal end moves longitudinally, the tab ***812*** releases the finger ***814***. Energy stored in the flexible arm ***802*** causes the mirror ***801*** to sweep through a scan path as indicated by the arrow ***824***. To provide additional energy, a helper spring ***826*** is coupled between the frame and the flexible arm ***808***.

[41] The resilient supports and flexible arms described above are designed to have a high "Q", typically greater than ***1000***, such that relatively little energy is lost from sweep to sweep. The design of high Q mechanical structures is generally well-known to one of skill in the art.

[42] The mirrored surface oscillates back and forth on the oscillating member ***156*** at a relatively constant frequency due to the high "Q" of the oscillating member. The optical energy is reflected off of the mirrored surface ***760*** as it oscillates causing the reflected optical energy to scan over a scan angle (θ) forming a scan path on a target.

[43] **FIG. 10** to shows one type of micro-electromechanical systems type of scanner ***758*** (MEMS scanner) suitable for this application. The MEMS scanner ***158*** is configured for uniaxial scanning with the mirrored surface ***760***. Design, fabrication and operation of such scanners are described for example in the Neukermans '790 patent, in Asada, et al, Silicon Micromachined Two-Dimensional Galvano Optical Scanner, IEEE Transactions on Magnetics, Vol. 30, No. 6, 4647-4649, November 1994, and in Kiang et al, Micromachined Microscanners for Optical Scanning, SPIE proceedings on Miniaturized Systems with Micro-Optics and Micromachines II, Vol. 3008, Feb. 1997, pp. 82-90 each of which is incorporated herein by reference. The scanner ***758*** includes integral sensors ***762*** that provide electrical feedback of the mirror position to terminals XXXX, as is described in the Neukermans '618 patent.

[44] The MEMS scanner ***758*** is constructed on a silicon substrate with a high reflectivity element ***760*** located on a central member ***762***. A set of support beams ***763*** and ***764*** suspend the central member ***762*** within a frame ***766***. The support beams ***763***, ***764*** define an axis (x) relative to the frame ***766*** about which the central member ***762*** rotates. A mechanical impact will set the MEMS scanner ***758*** into an oscillating condition. To improve the response of the scanner ***758*** to an impact, the central member ***762*** is positioned a symmetrically relative to the support beams ***763*** and ***764***. Once driven into motion, the high Q characteristic of the MEMS scanner ***758*** allows the MEMS scanner ***758*** to mechanically oscillate at a particular frequency or in a relatively

narrow frequency range, thereby pivoting the central member ***762*** mechanically through an angular sweep.

[45] A mechanical impact or vibration transfers mechanical energy to the MEMS scanner ***758***, causing it to oscillate. The scan angle (θ for the x-axis) is a function of the oscillation range of the MEMS scanner ***758***.

[46] Examples of MEMS scanners are described in U.S. Patent No. 5,629,790 to Neukermans et al., entitled MICROMACHINED TORSIONAL SCANNER, U.S. Patent No. 5,648,618 to Neukermans et al., entitled MICROMACHINED HINGE HAVING AN INTEGRAL TORSIONAL SENSOR and CITE DICKENSHEETS PATENT INSTEAD, each of which is incorporated herein by reference. Additionally, the scanning system may be configured to incorporate a non-MEMS mechanically resonant scanner such as disclosed in U.S. Patent No. 5,557,444, Melville et al. entitled MINIATURE OPTICAL SCANNER FOR A TWO-AXIS SCANNING SYSTEM, which is incorporated herein by reference.

[47] **FIG. 11** shows the front and rear of an alternative scanner ***900*** that may be formed using injection molding or similar techniques. Initially, he scanner ***900*** is formed as an integral piece having a frame ***902***, a central body ***904***, and arms ***906***. Once the integral piece is formed, a suspension wire ***910*** is coupled between the frame ***902*** and central body ***904*** under a relatively high tension and held in place by a set of guide pins ***912***. Once the suspension wire ***910*** is in place, the arms ***906*** are removed, as indicated by the cross hatching, thereby leading the central body ***904*** suspended relative to the frame ***902*** by the suspension wire ***910***.

[48] As best seen in **FIG. 12**, the central body ***904*** includes an offset weight ***914*** so that upon impact, as described above, the central body ***904*** will oscillates about the suspension wire ***910***. While the offset weight ***914*** is shown as an integral piece, other asymmetries can be introduced to the central body ***904***, such as added masses, hollowed portions, or non homogenous sections.

[49] Each of the previously described embodiments includes a central body that pivots about a torsion arm or a body that travels in response to a flexible member.

FIGS. 13 and **14** show to an alternate scanning assembly ***1200*** where a lead screw ***1202*** drives a polygon ***1204*** carried on axle ***1206*** by a bearing ***1208***. The scanning assembly is similar to many children's toys in which a user depresses a pushbutton ***1212*** causing a lead screw ***1202*** to slide through a drive disk ***1212***. As the lead screw ***1202*** slides through the drive disk ***1212***, the spiral surfaces of the lead screw ***1202*** causing the drive disk to rotate about the axle ***1206***. As the drive disk rotates, it causes reflected surfaces of the polygon ***1204*** to travel about the axle ***1206***. The reflected surfaces can scan the beam in a similar fashion to conventional barcode scanners.

[50] Another spinning polygon approach is shown in **FIG. 15** in which a user activated button ***1502*** drives a gear rack ***1504***. The gear rack pivots a pinion ***1506*** that transfers motion to a polygon ***1510*** through a pair of bevel gears ***1512***, ***1514***. To allow the polygon ***1510*** to continue spinning after the user releases the button ***1502***, the lower bevel gear ***1514*** is coupled to the polygon ***1510*** by a one-way clutch.

[51] While a variety of approaches have been described herein to actuating a scanning system using user power, the invention is not so limited. The in fact, in some applications, the user power may be replaced by an escapement mechanism as is shown in **FIGS. 16** and a **17**. In this embodiment, a user or a spring mechanism applies relatively constant longitudinal force to a rack ***1610***. The force causes an escape wheel ***1612*** to pivot about axle ***1614*** such that teeth ***1616*** sequentially engage drive pins ***1618***, ***1620***. The drive pins cause a Y-arm ***1622*** to oscillate back and forth about a support arm ***1624***. The Y-arm ***1622*** drives a support shaft ***1632*** cause a balanced wheel ***1633*** to pivot back and forth, while a hairspring ***1636*** provides return force. While one type of escapement is presented in **FIGS. 16** and **17**, one skilled in the art will recognize that a variety of similar structures as are commonly found in spring driven watches could be adapted for such an application.

[52] Still another approach to actuating a mirror ***1900*** is shown in **FIG. 19**, in which a thumb lever ***1902*** drives an arm ***1904*** downwardly as guided by a finger ***1906*** in a slot ***1908***. The arm ***1904*** pulls an elastomeric support ***1910*** causing it to band about a

necked-down region ***1912***. As the user releases the thumb lever ***1902***, the elastomeric support ***1910*** springs back, carrying arm ***1904*** and mirror ***1900*** through scan path.

[53] **FIG. 20** shows another mechanism in which a user depresses a pushbutton ***2000*** to drive a shaft ***2000*** to downwardly. A pin ***2004*** guides in opposite end of the shaft ***200*** to through a track guide ***2006*** so that a finger ***2008*** begins traveling downwardly. When the pin ***200*** for reaches a lower knee ***2010***, the pin begins to travel laterally as indicated by the arrow ***2012***, assisted by a helper spring ***2014***. As the pin travels laterally, the pin releases a resilient mirror arm ***2015***. As described above, with respect to several other embodiments, the mirror arm ***2015*** springs back to its original position until it reaches a stop ***2022***, thereby initiating scanning.

[54] As the user releases pressure, a return spring ***2016*** pushes the arm ***200*** to upwardly so that the pin follows the track ***2006*** through an offset return past ***2020***. The finger ***2008*** then returns to its rest position directly above the mirror arm ***2015***.

[55] While a variety of embodiments of a scanning imaging system have been described herein, one skilled in the art may implement the subject matter herein in a variety of manners. For example, the imaging system described herein has been described with reference to bar code scanning. However, the scanning techniques described herein may relate to other image capture systems or to systems for displaying an image. Accordingly, the invention is not limited except as by the appended claims.

[56] **FIG. 21** is an exploded view of a handheld barcode scanner ***3000*** that sweeps a scan beam (not shown in **FIG. 21**) using kinetic energy supplied by an operator (not shown) according to an embodiment of the invention. Consequently, the scanner ***3000*** uses less electrical energy to sweep the scan beam and can be smaller than barcode scanners that use a motor or other electrically powered means to sweep the scan beam.

[57] The scanner ***3000*** includes a hand-holdable housing ***3002***, which has top and bottom covers ***3004*** and ***3006*** and a scan window ***3008***, a printed circuit board ***3010*** mounted within the housing ***3002***, a beam source ***3012*** and an optional processor ***3013*** mounted to the circuit board, a piezo-electric crystal ***3014***, and a battery holder

3016. The beam source ***3012*** includes a light source ***3018***, such as a Light-Emitting Diode (LED) or laser diode, and a scan button ***3020***, which respectively protrude through LED and button openings ***3022*** and ***3024*** in the top cover ***3004***. The beam source ***3012*** also includes an electrical pad ***3026*** that electrically contacts the printed circuit board ***3010*** to provide power to the beam source ***3012*** from a battery (not shown) when the operator (not shown) presses the scan button ***3020***. A cable ***3028*** is coupled to the printed circuit board ***3010*** via a connector ***3030*** and allows a remote device (not shown) such as a processor or base unit to communicate with the scanner ***3000***.

[58] In operation according to an embodiment of the invention, the operator (not shown) pushes the scan button ***3020*** with his thumb to scan a target such as the bar-code symbol ***190*** (**FIG. 1**), and releases the button to reset the scanner ***3000***. First, the operator grasps the housing ***3002*** with his hand and finds the opening ***3024*** with his thumb. The opening ***3024*** is tapered to guide the operator's thumb to the scan button ***3020***. Next, the operator aligns the scan window ***3008*** with the target and pushes the button ***3020***, which causes the pad ***3026*** to electrically couple the beam source ***3012*** to a battery (not shown) in the battery holder ***3016*** via the printed circuit board ***3010***. The beam source ***3012*** uses power from the battery to generate and emit a scan beam (**FIG. 24**). At the same time, the beam source ***3012*** uses the movement of the button ***3020*** to sweep the scan beam across the target. The beam source ***3012*** detects a return beam (**FIG. 24**), which is the portion of the scan beam that is reflected from the target, and converts the return beam into an electrical signal. A remote device (not shown) receives the electrical signal via the cable ***3028***, recovers information about the target from the electrical signal, and informs the beam source ***3012*** whether the recovered information is valid. For example, where the target is a bar-code symbol, the remote device informs the beam source ***3012*** whether the recovered information represents a valid symbol. If the information is valid, then the beam source ***3012*** stores the information in a memory (not shown) and activates the piezo-electric crystal ***3014*** and the LED ***3018*** to audibly and visibly notify the operator that the scan of the target was successful. Conversely, if the information is invalid, then the beam source ***3012*** does not activate the crystal ***3014*** or the LED ***3018***. Alternatively, the beam source ***3012*** may

activate the crystal ***3014*** and the LED ***3018*** to generate respective information-valid and information-invalid sequences. Furthermore, instead of the remote device, the processor ***3013*** may determine whether the recovered information is valid and activate the crystal ***3014*** and LED ***3018*** as appropriate. Next, the operator releases the button ***3020*** to reset the scanner ***3000*** for the next scan.

[59] **FIG. 22** is an isometric view of the beam source ***3012*** of **FIG. 21** with its top cover removed according to an embodiment of the invention. For clarity, the LED ***3018*** is omitted from **FIG. 22**. In addition to the scan button ***3020*** and the pad ***3026***, the beam source ***3012*** includes a reflector assembly ***3040*** for sweeping the scan beam (not shown), a sweep mechanism ***3042*** for activating and deactivating the reflector assembly, and a beam-generate/detect assembly ***3044***. The reflector assembly ***3040*** includes a multi-faceted mirror ***3046*** — here the mirror has three faces, although it may have one, two, or more than three faces — a magnet ***3048***, and a shaft ***3050*** about which the mirror and magnet can rotate. The sweep mechanism ***3042*** includes a magnet ***3052*** for driving and retaining the reflector assembly ***3040***, a magnet holder ***3054***, a magnet retainer ***3056***, a magnet guide ***3057***, and spring-loaded (spring not shown) magnet-moving members ***3058*** and ***3060***. Both the reflector assembly ***3040*** and the sweep mechanism ***3042*** are shown in their home positions in **FIG. 22**. The beam-generate/detect assembly ***3044*** includes a laser diode ***3062*** (shown in **FIG. 24**) for generating the scan beam, a photo diode ***3064*** for detecting the return beam reflected from the scanned target (not shown), and a guide, *i.e.*, straw, ***3065*** for guiding the return beam to the photo diode. The assembly ***3044*** also includes a stationary mirror ***3066*** for deflecting the scan beam from the laser diode ***3062*** to the mirror ***3046*** and for deflecting the return beam from the mirror ***3046*** to the photo diode ***3064***.

[60] **FIG. 23** is an isometric view of the beam source ***3012*** of **FIG. 22** with the sweep mechanism ***3042*** in its sweep position and the reflector assembly ***3040*** in its zero sweep position according to an embodiment of the invention. As discussed below, the reflector assembly ***3040*** rotates back and forth, *i.e.*, oscillates, about its zero sweep position while sweeping the scan beam (not shown in **FIG. 23**) across the target (not shown).

[61] **FIG. 24** is an isometric view of the beam source ***3012*** of **FIG. 23** with the scan button ***3020*** omitted to expose the laser diode ***3062*** and including the scan beam ***3070*** (solid line) and the return beam ***3072*** (dashed line) according to an embodiment of the invention. The laser diode ***3062***, photo diode ***3064***, and straw ***3065*** are positioned so that the beams ***3070*** and ***3072*** converge at a predetermined convergence distance from the scan window ***3008*** (**FIG. 21**). In one embodiment, this distance is or approximately is six inches. Consequently, the operator typically learns to hold the scanner ***3000*** (**FIG. 21**) such that the scan window ***3008*** is or approximately is the convergence distance away from the target (**FIG. 1**). Alternatively, one can reposition the laser diode ***3062***, photo diode ***3064***, and/or straw ***3065*** to change the convergence distance of the beams ***3070*** and ***3072***.

[62] The operation of the scanner ***3000*** according to an embodiment of the invention is discussed below in conjunction with **FIGS. 21 – 24**.

[63] To deactivate the scanner ***3000*** such that it does not scan a target (not shown), an operator (not shown) releases the scan button ***3020*** or merely allows the scan button to remain in its unpushed position as shown in **FIG. 22**. When the scan button ***3020*** is released, the reflector assembly ***3040*** and sweep mechanism ***3042*** are in their respective home positions as shown in **FIG. 22**. Specifically, the mechanism ***3042*** positions the magnet ***3052*** such that it attracts the magnet ***3048***. Because the assembly ***3040*** is free to rotate about its shaft ***3050***, this magnetic attraction forces the mirror ***3046*** to face away from the mirror ***3066***, and thus prevents the mirror ***3046*** from sweeping the scan beam ***3070*** or directing the return beam ***3072***. Furthermore, the pad ***3026*** does not contact the printed circuit board ***3010***, thus cutting off power to the laser diode ***3062*** and the detector ***3064***. Consequently, the scanner ***3000*** cannot generate or sweep the scan beam ***3070*** while the scan button ***3020*** is released.

[64] To activate the scanner ***3000*** to scan a target (not shown), the operator (not shown) pushes the scan button ***3020*** as shown in **FIGS. 23** and **24**. When the scan button ***3020*** is pushed, the printed circuit board ***3010*** provides power from the battery (not shown) in the holder ***3016*** to the laser and photo diodes ***3062*** and ***3064*** via

the pad ***3026***; consequently, the laser diode generates the scan beam ***3070***. Furthermore, the reflector assembly ***3040*** oscillates to sweep the beam ***3070*** across the target and to direct the return beam ***3072*** to the photo diode ***3064***. Specifically, referring to **FIGS. 23** and **24**, the pushed button ***3020*** moves the members ***3058*** and ***3060*** downward, and thus causes the members to position the magnet ***3052*** such that it repels the magnet ***3048***. Because the assembly ***3040*** is free to rotate about its shaft ***3050***, this magnetic repulsion forces the magnet ***3048*** away from the magnet ***3052***, and thus forces the mirror ***3046*** toward the magnet ***3052***. The stable (after a settling time) sweep positions, *i.e.*, the zero sweep positions, to which the magnet ***3052*** respectively forces the mirror ***3046*** and magnet ***3048*** are shown in **FIGS. 23** and **24**. But because the shaft ***3050*** encounters little resistance, the magnet ***3048*** and mirror ***3046*** oscillate back and forth about these respective zero sweep positions for a period of time, typically a few seconds. This oscillation is further discussed below in conjunction with **FIGS. 25A** and **25B**. During this period, the oscillating mirror ***3046*** sweeps the beam ***3070*** across the target at least once, and typically sweeps the beam back and forth across the target multiple times. In an alternative embodiment, a spring (not shown) may be attached to the reflector assembly ***3040*** to reinforce or dampen the oscillations.

[65] Still referring to **FIGS. 21-24**, if the scan is successful, the scanner ***3000*** signals the operator (not shown), who then releases the scan button ***3020*** to reset the scanner and ready it for another target (not shown). Specifically, the remote device (not shown) coupled to the scanner ***3000*** via the cable ***3028*** reads the detected return beam ***3072*** and determines whether a valid target is detected. If so, the remote device signals the scanner ***3000***, which lights the LED ***3018***, generates a beep with the piezo-electric crystal, or does both in a recognizable pattern to let the operator know that the scan was successful.

[66] If the scan is unsuccessful, the scanner ***3000*** signals the operator (not shown), who then releases the scan button ***3020*** to reset the scanner and ready it for rescanning the target. Specifically, if the remote device determines that a valid target was not detected within a predetermined period of time, the remote circuit signals the scanner ***3000***, which lights the LED ***3018***, generates a beep with the piezo-electric

crystal, or does both with a predetermined pattern to let the operator know that the scan was unsuccessful. Alternatively, the remote device may send no signal, and the operator recognizes that an unlit LED ***3018*** and/or no beep within a predetermined period of time indicates an unsuccessful scan. The operator then can rescan the target according to the scan procedure described above.

[67] **FIG. 25A** is a cross-sectional view of the reflector assembly ***3040*** in its home position and of the magnet ***3052*** in its home and sweep positions according to an embodiment of the invention. In one embodiment, the magnet ***3052*** is a flexible multi-pole magnet that is rectangular and that has two opposite poles at each end. For example purposes, assume that the magnet ***3052*** has the labeled North (N) and South (S) pole configurations, although it may have the opposite pole configurations where all N's become S's and vice-versa. The magnet ***3046*** may be made from the same material as the magnet ***3052***, but is a standard dipole magnet in the disclosed embodiment. The three-dimensional pole pattern of the magnet ***3052*** is shown below in **FIG. 25B**.

[68] When the magnets ***3048*** and ***3052*** are in their respective home positions as shown in **FIG. 25A**, the N and S poles of the magnet ***3052*** are aligned with the S and N poles, respectively, of the adjacent end of the magnet ***3048***. Therefore, the magnets ***3048*** and ***3052*** attract one another. Because the sweep mechanism ***3042*** holds the magnet ***3052*** in a fixed position and the assembly ***3040*** is free to rotate, the attraction between the magnets moves the magnet ***3048*** to its home position when the magnet ***3052*** is in its home position regardless of the initial position of the magnet ***3046***. In their respective home positions, the magnets ***3048*** and ***3052*** may be touching one another.

[69] When the magnet ***3052*** moves into its sweep position as shown in **FIG. 25A**, its N pole is aligned with the N pole of the magnet ***3048***. Therefore, the magnets ***3046*** and ***3052*** repel one another. Because the sweep mechanism ***3042*** holds the magnet ***3052*** in a fixed position and the assembly ***3040*** is free to rotate, the repulsion between the magnets moves the magnet ***3046*** as far as possible away from the magnet ***3052***. Because the reflection assembly ***3040*** is underdamped, this repulsion also

causes the reflection assembly to oscillate back and forth and sweep the scan beam ***3070*** (**FIG. 24**) for a period of time as discussed above in conjunction with **FIGS. 21 – 24**.

[70] To prevent the magnet ***3052*** from pushing and/or scraping against the magnet ***3048*** as the magnet ***3052*** moves from its home position to its sweep position, the sweep mechanism ***3042*** (**FIGS. 22 – 24**) moves the magnet ***3052*** along a path ***3080*** or along a similar path. Specifically, the mechanism ***3042*** directs and keeps the magnet ***3052*** away from the magnet ***3048*** until the magnet ***3052*** is below the bottom level of the magnet ***3046***. Then, the mechanism ***3042*** moves the magnet ***3052*** beneath the reflector assembly ***3040*** so that the magnets ***3048*** and ***3052*** read one another. How the mechanism ***3042*** moves the magnet ***3052*** is discussed below in conjunction with **FIGS. 26** and **27**.

[71] **FIG. 25B** is an isometric view of the magnet ***3052*** of **FIG. 25A** according to an embodiment of the invention. The magnet ***3052*** has the same pole configuration as two dipole magnets stacked one atop the other, even where the magnet ***3052*** is a single piece of magnetic material.

[72] **FIG. 26** is a side view of the reflector assembly ***3040*** and the magnet guide ***3057*** of the sweep mechanism ***3042*** (**FIGS. 22 – 24**) according to an embodiment of the invention. The guide ***3057*** includes a guide channel ***3082***, which forces the magnet ***3052*** to move between its home and sweep positions without scraping or pushing against the magnet ***3048*** as described above in conjunction with **FIG. 25**.

[73] **FIG. 27** is an isometric view of the magnet ***3052***, magnet holder ***3054***, and magnet retainer ***3056*** of the sweep mechanism ***3042*** (**FIGS. 22 – 24**) according to an embodiment of the invention. The magnet ***3052*** is attached to the holder ***3054*** with adhesive or via another conventional technique. The holder ***3054*** can slide horizontally within tracks ***3084*** of the retainer ***3056***, and thus allows the magnet ***3052*** to move toward and away from the reflective assembly ***3040*** as discussed above in conjunction with **FIG. 25**. The retainer ***3056*** can move up and down within the guide ***3057*** (**FIGS. 22-24** and **26**), and thus allows the magnet ***3052*** to move above and below the bottom

level of the magnet ***3048*** as discussed above in conjunction with **FIG. 26**. The holder ***3054*** includes posts ***3088*** (only one post shown in **FIG. 27**), which ride within the guide channel ***3082*** of **FIG. 26**. Consequently, the magnet ***3052*** moves between its home and sweep positions without scraping the magnet ***3048*** as described above in conjunction with **FIG. 25**.

[74] Although **FIGS. 25 – 27** describe a technique for preventing the magnet ***3052*** from pushing against and scraping the magnet ***3048*** as it moves between its home and sweep positions, other techniques can be used.

[75] **FIGS. 28** and **29** are isometric views of the beam source ***3012*** of **FIG. 21** according to another embodiment of the invention. The beam source ***3012*** of **FIGS. 28** and **29** is similar to the beam source ***3012*** of **FIGS. 22 – 24** except for the addition of a trigger mechanism ***3100***, which includes a spring-loaded lever arm ***3102*** and a trigger spring ***3104***. As discussed below, the trigger mechanism ***3100*** causes the sweep mechanism ***3042*** to move the magnet ***3052*** (**FIGS. 22 – 25**) between its home and sweep positions at the same or approximately the same speeds regardless of the speed or force with which an operator (not shown) pushes the scan button ***3020*** (**FIGS. 22-24**). Referring to **FIGS. 22 – 24**, the operator can push the button ***3020*** at any speed and to any distance he desires. If the operator does not push the button ***3020*** all the way in, then the magnet ***3052*** may stop somewhere between its home and sweep positions, and thus not activate the reflector assembly ***3040***. Or, if the operator pushes the button ***3020*** too slowly, then the amplitude of the mirror ***3046*** oscillation may be too small to adequately sweep the beam ***3070*** across the target (not shown). The disclosed embodiment of the trigger mechanism ***3100*** prevents these potential malfunctions by moving the magnet ***3052*** the full distance and at a predetermined speed when the lever arm crosses the home-to-sweep and sweep-to-home trigger thresholds as discussed below. The trigger mechanism ***3100*** also provides a “click” or other sound or vibration that notifies the operator that he has pushed the button ***3020*** far enough to commence a scan of the target.

[76] Referring to **FIG. 28**, the lever arm ***3102*** is in its up position (shown) when the scan button ***3020*** (**FIGS. 21 – 24**) is released. As the operator (not shown) presses the scan button ***3020***, it pushes against the lever arm ***3102***, thus forcing the arm downward. As the arm ***3102*** moves downward, the spring ***3104*** extends. As the arm ***3102*** passes the home-to-sweep trigger threshold, which, in one embodiment, is the point where the arm is horizontal, the extended spring ***3104*** quickly pulls the magnet-moving member ***3060*** downward. This causes the magnet ***3052*** (**FIGS. 22-25**) to move in a single motion from its home position to its sweep position, where the magnet causes the mirror ***3048*** to sweep the scan beam ***3070*** as discussed above in conjunction with **FIGS. 22 – 25**.

[77] Referring to **FIG. 29**, the lever arm ***3102*** is in its down position (shown) when the scan button ***3020*** (**FIGS. 21 – 24**) is fully pushed. As the operator (not shown) releases the scan button ***3020***, a spring (not shown) forces the lever arm ***3102*** upward. As the arm ***3102*** moves upward, the spring ***3104*** extends. As the arm ***3102*** passes the sweep-to-home trigger threshold, which, in one embodiment, is the point where the arm is horizontal, the extended spring ***3104*** quickly pulls the magnet-moving member ***3060*** upward. This causes the magnet ***3052*** (**FIGS. 22-25**) to move in a single motion from its sweep position to its home position, where the magnet causes the mirror ***3048*** to move to and stay in its home position as discussed above in conjunction with **FIGS. 22 – 25**. Because the arm ***3102*** is spring loaded, the members ***3058*** (**FIGS. 22 – 24**) and ***3060*** need not be spring loaded.

[78] The foregoing discussion is presented to enable a person skilled in the art to make and use the invention. Various modifications to the embodiments will be readily apparent to those skilled in the art, and the generic principles herein may be applied to other embodiments and applications without departing from the spirit and scope of the present invention as defined by the appended claims. For example, a variety of mechanisms may be employed to move one magnet relative to the other. Additionally, in some configurations, the mirror may sweep only one or very few times in response to operator activations. Moreover, the scanning mechanisms described herein may be applied to targets other than bar-code symbols. Further, while the

scanner embodiments described herein include a processing circuit ***3013***, the processing circuit or other components may be located remotely or incorporated in other devices. In some configurations, the scanner ***3000*** may be coupled directly to a portable computer, PDA, or cellular phone. In such configurations, the scanner ***3000*** may provide unprocessed data and use processing power in the remote devices to identify information about the target. Additionally, for some applications, it may be desirable to use a linear array in place of the photo diode ***3064*** to image more than a single line. Additionally, although the embodiment described herein scans along a single axis, in some applications, the mirror support may be configured such that the mirror sweeps the beam through a two dimensional scan pattern, such as an ellipse or a more complex pattern. Also, although the magnet ***3048*** is shown as being discrete from the mirror ***3046***, the invention is not so limited. In an alternative configuration, the mirror ***3046*** may be mounted directly on the magnet ***3048*** or the mirror ***3046*** may be formed on a face of the magnet ***3048***. Furthermore, any combination or subcombination of the disclosed embodiments is possible. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.